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Green synthesis of graphene oxide from invasive plant species (Nymphaeaceae) for enhancing cement paste microstructure and compressive strength

Gowhar Afzal *, Tanveer Rasool

Department of Chemical Engineering at National Institute of Technology Srinagar-190006, India

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ABSTRACT

The proliferation of invasive species, particularly water lilies (*Nymphaeaceae*), in aquatic ecosystems, such as Dal Lake in Srinagar, J&K, India, has led to significant challenges for aquatic life. This research addresses this issue by harnessing the invasive water lily as a resource for an environmentally conscious approach to produce graphene oxide (GO) through thermal pyrolysis. The synthesized GO was incorporated into cement paste (CP) (ranging from 0 to 0.09 wt%) to explore its impact on workability, mechanical properties, and microstructure. Increasing GO concentrations led to decreased workability. However, GO positively influenced compressive strength, with optimal enhancements observed at 0.06 %, a maximum enhancement in compressive strength of 53.7 % and 35.4 % at 7 and 28 days when compared to the control CP. Microstructure analysis through FE-SEM revealed improved cement hydration, pore filling, and densified microstructure, supported by XRD and FT-IR findings. Specifically, GO at 0.06 % concentration showed notable improvements, indicating its crucial role in enhancing mechanical properties.

1. Introduction

Graphene Oxide (GO) is widely recognized as one of the most robust materials available, potentially revolutionizing material science and technology fields. Compared to other functionalized graphene-based derivatives (Devi and Khan, 2020), GO exhibits exceptional mechanical, electrical, chemical, and thermal properties. Furthermore, it possesses anti-corrosion, energy efficiency, and self-cleaning capabilities (Shamsaei et al., 2018). Serving as the fundamental structure for various allotropes, graphene often referred to as the 'wonder material,' underscores the significance of GO. Graphite can be converted to GO, which forms a few or single graphene layers after reduction. The oxidizing agent increases interplanar spacing among graphite layers, producing GO as a by-product (Paulchamy et al., 2015; Ankamwar and Surti, 2012; Ban et al., 2012; Mattevi et al., 2009; Su and Loh, 2013). Diverse methodologies have been employed in preparing Graphene oxide and its derivatives, encompassing chemical vapour deposition, epitaxial growth, and micromechanical exfoliation of graphite, each varying in quality and quantity (Shams et al., 2015; Novoselov et al., 2004; Reina et al., 2009; Sutter, 2009; Chakrabarti et al., 2011). Hummer's Method is a commonly used approach for manufacturing graphene oxide, noted for its scalability and ability to create highly oxidized GO. However, it includes toxic chemicals like potassium permanganate and may be time-consuming, possibly leading to degradation of the graphene structure. Epitaxial Growth generates high-quality, single-layer GO sheets with exquisite control over layers and faults. While it assures high purity and regulated qualities, the approach needs complicated equipment and exact conditions, making it costly and less scalable. Exfoliation processes, including as ultrasonic and chemical exfoliation, are uncomplicated and help maintain graphene integrity. These technologies frequently generate lesser quantities of GO and allow less control over sheet size and quality, which might be limiting for large-scale applications. Electrochemical Methods are ecologically friendly and employ gentler conditions. They give excellent control over GO's oxidation level and homogeneity. However, they need specialized equipment and encounter obstacles in scaling up for large-scale manufacturing (Shams et al., 2015; Novoselov et al., 2004; Reina et al., 2009; Sutter, 2009; Chakrabarti et al., 2011).

Among these, the oxidation of graphene to synthesise Graphene oxide is the most prevalent and favored technique, renowned for its scalability and high-quality production compared to other methods. Mechanical exfoliation also holds promise as a viable approach for large-

* Corresponding author.
E-mail addresses: gowhar_11phd19@nitsri.ac.in (G. Afzal), tanveer@nitsri.ac.in (T. Rasool).

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